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Forge Note Book

Arranged by

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Milwaukee, Wis.

To the Instructor.

This is intended to be a reference note book giving the necessary information regarding the tools used, operations and processes in Forge; also providing extra space for the student to make drawings and to write any special information the instructor may give.

To the Student.

An apron of heavy canvas or leather should be worn by the student in the forge shop.

You should know each tool and operation by its proper name.

See that you have the proper tools and information before taking your exercise from the fire. It is too late when the exercise is on the anvil and will require extra heats. A blacksmith's efficiency is judged by the number of heats he takes to complete a job.

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FORGE NOTE BOOK

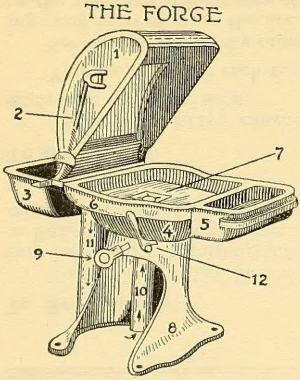

Fig. 1.

1. Down draught hood.
2. Handle to operate hood.
3. Coal tank.
4. Fire pot.
5. Water tank.
6. Pan.
7. Tuyeres.
8. Base.
9. Ash dump.
10. Blast pipe.
11. Smoke or exhaust pipe.
12. Blast lever.

Fig. 1. The forge is the place on which the fire is built. The fire is started directly over the tuyere, which is 3″ to 8″ deep. The tuyere has a number of small holes through which the air or blast passes. If there are a number of forges in the shop the air is generally furnished by power blowers or fans. The air pressure is from 5 to 8 oz. to the square inch.

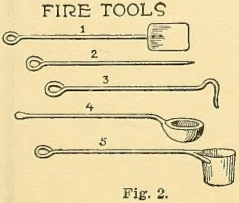

Fig. 2.

1. Shovel
2. Poker.
3. Rake.
4. Dipper.
5. Sprinkler.

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BUILDING AND STARTING A FIRE.

The fireplace must be cleaned before starting a fire. Any coke found is broken up and put aside to be used for fuel. The unburnt coal is separated from the clinkers and dust, and mixed with green coal for the walls of the new fire.

To start the fire, place paper, shavings, finely split wood, charcoal or oily waste directly over the tuyere, and light it. Then add coke and bank with damp green coal, packing it down slightly. This should be continued until the fire reaches the proper height.

Another method is to place a slightly tapered block of wood about 3" x 3" x 12" over the tuyere, after which coal is packed around the block until the proper height is reached. Banks of dampened green coal are placed on each side and sometimes at the back. The block is then rapped and withdrawn and the fire is started at the bottom, directly over the tuyere. Coke is added as needed.

FUEL.

Soft coal is the fuel most generally used for blacksmith fires. It must be soft coal of the purest kind as iron and steel absorb impurities such as sulphur and phosphorous after a red heat is reached, which should be avoided, especially in tool steel.

Hard coke is used in furnaces of the larger sizes. This is soft coal with the impurities taken out in coke ovens by intense heat. It is the fuel used in the blast furnaces.

Crude oil is taking the place of coke in furnaces to a great extent. It is piped to the furnace and regulated by valves thus doing away with hauling and shoveling, and also eliminating the dirt and dust. Gas is used in the same way and for the same purpose.

Charcoal is the purest fuel known and should be used when possible on tool steel, for the reason that it adds a certain amount of carbon to the steel whereas most fuels extract a certain amount. Charcoal is not used more extensively because it heats metal very slowly and also is very expensive.

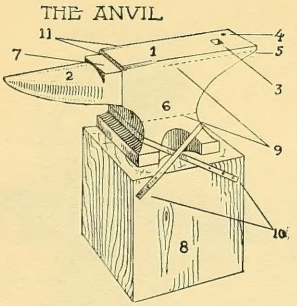


Fig. 3.

1. Face.
2. Horn.
3. Hardy-hole.
4. Pritchel-hole.
5. Heel.
6. Base.
7. Cutting block.
8. Anvil block.
9. Welded here.
10. Straps to fasten anvil to block.
11. Rounded here.

Fig. 3. The anvil is indispensable, for upon it the smith can shape or form nearly any kind of forge work. The shape seems to be fitted for all requirements, and has not been changed for centuries. The best anvils are made of wrought iron. They are composed of three pieces: First, the base which is forged to required dimensions; second, the top which includes the horn and the heel. These are welded together along the lower broken line. Third, the face of tool steel which is welded to the top at the place shown by the upper broken line. The face is finished and hardened, and is then ground perfectly true lengthwise but slightly convex crosswise to help in drawing out metals. The corners are slightly rounded a distance of about 4" from the end nearest the horn.

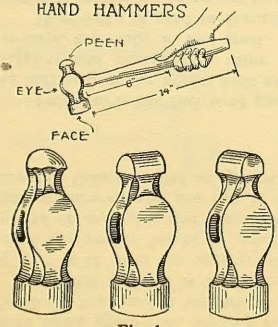


Fig. 4.

Fig. 4. The hand hammers used in the blacksmith shop are ball peen, straight peen, cross peen, and square faced with a cross peen. The ball peen is generally used and should weigh about 1½ lbs. The handle must be put in straight and at right angles to a line through the center of the peen and face. The handle should be grasped at least two-thirds of the way back.

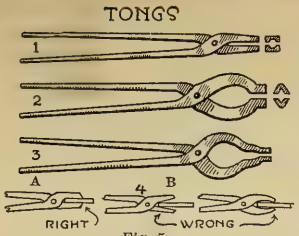


Fig. 5.

Fig. 5. Flat tongs are made with one groove lengthwise of the lips and one crosswise near the end. These tongs will hold round, flat or square stock, also links.

The "V" shaped hollow bit tongs will hold round, square or octagonal stock.

The pick-up tongs. As the name implies, they are used to pick up small or large irregular shapes. They are also used to grip short pieces of round or square stock being worked on end.

The jaws of the tongs should fit the stock they are holding their entire length as "A" in illus. 4, otherwise the piece held will be liable to turn or fly out of the tongs and cause an accident. In using flat tongs the opening should always be toward the side. If the opening is upward the piece is liable to fly up and hit the blacksmith.

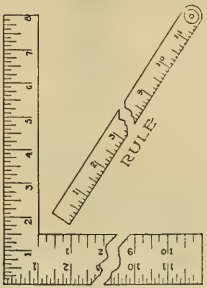


Fig. 6.

Fig. 6. The rule is used to measure distances. The graduated part of the rule should be brought as close as possible to the part being layed off.

The best rules for blacksmiths are made of brass and will not rust like steel nor burn like wood.

The student should use a sharp piece of soapstone or scratch-awl to make a mark in laying out his exercise.

Always have your work inspected by the instructor before beginning, as it will save needless labor, should there be any mistakes.

The square is used to try right angles and surfaces, and to lay them off accurately.

In laying off work, first mark it correctly with soapstone, chalk or the scratch-awl, then mark with a center punch. Never mark with a cold chisel except when the material is to be cut off.

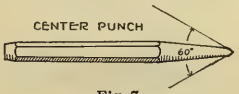


Fig. 7.

Fig. 7. Work to be heated is first layed off with the rule and square, then marked with the center punch. The center punch is also used for laying out the center of a hole that is to be drilled.

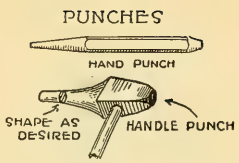


Fig. 8.

Fig. 8. Punches are of various sizes and shapes. They are used to punch holes in hot material. A punch held in the hand and driven through with the hand hammer is used for light work. All punches for heavy work should have a handle so as to avoid burning the hand. They are driven through the metal by the helper with a sledge hammer or with the power hammer.

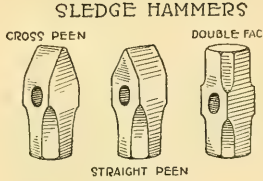


Fig. 9.

Fig. 9. Sledge hammers weigh from 4 to 24 lbs. The most common in use weigh from 8 to 12 lbs. They are of three different kinds: Cross peen, straight peen and double faced. The straight peen is the common one in commercial shops. Sledge hammers are used by the blacksmith's helper on work too heavy for the hand hammer and for striking on handled tools. The smaller ones are usually called backing hammers.

Fig. 10.

Fig. 10. Flatters are used to remove rough places and hammer marks from flat or square forgings. The face of the flatter is about 2½" square and perfectly straight excepting the outer edges which should be slightly lower to prevent marking the work.

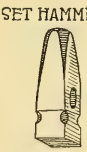


Fig. 11.

Fig. 11. The square set hammer is used to make square shoulders or depressions and for drawing metal between two shoulders or projections. The round edge set hammer is used for the same purposes, but it produces a rounded fillet instead of a square corner. Set hammers often take the place of the hand hammer in drawing, and of the flatter in small narrow places.

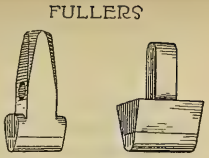


Fig. 12.

Fig. 12. Top and bottom fullers have rounded faces. Top fullers are used to widen work when it is not necessary to lengthen the same. The material is drawn at right angles to the fuller. These tools are also used to make depressions for shoulders or projections. They leave a fillet which is very necessary to strong forgings and should always be left when possible. The top and bottom fullers are used together when the shoulders or projections are on opposite sides of the forging. Top fullers are made for a handle and bottom fullers with a shank to fit the hardy-hole.

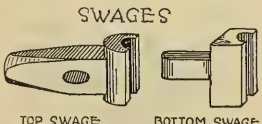


Fig. 13.

Fig. 13. Top and bottom swages are made with semi-circular grooves of various sizes to suit the forging. The top has an eye in which to fit a handle, and the bottom has a shank to fit loosely into the hardy-hole. These tools are used for smoothing round stock. Swages are also made for octagonal, hexagonal and other shapes.

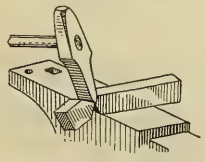


Fig. 14.

Fig. 14. Hot cutters are used for cutting hot stock. The stock behind the cutting edge is drawn thin to prevent the sides from binding in the cut. Because the hot cutters are tempered a little, cold water should be near at hand to cool them off so as not to draw the temper.

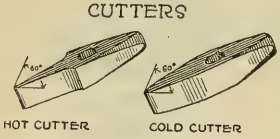


Fig. 15.

Fig. 15. Cold cutters are used to nick cold iron and steel for breaking, or for marking forgings that will have to be cut hot. They should be tapered to a blunt edge and should have plenty of stock behind the cutting edge as these cutters have heavy blows to withstand. They should be tempered as soft as will do the work; if too hard the edge is liable to break.

The cutting edge of both these tools should be ground to an angle of about 60 degrees.

Caution—Do not cut hot, flat or square iron off from one side. Cut about two-thirds through, then turn over and finish cutting from the other side, shoving the part to be cut off just over the outside edge of the anvil. If the stock is cut off on the face of the anvil, it is liable to fly upwards and the cutting edge of the chisel will be destroyed.

When cutting off hot round iron, the stock should be placed in a bottom swage of the same diameter and cut all the way around until nearly through. Then the cut should be shoved over the edge of the anvil and cut off. The shape of hot round stock will be destroyed if cut on the flat of the anvil.

HARDY

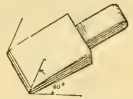


Fig. 16.

Fig. 16. The hardy is used instead of the hot or cold chisels when there is no helper.

GOUGE

Fig. 17.

Fig. 17. The gouge is similar to the hot chisel. The blade is formed so as to give a semi-circular cutting edge of any desired radius. The gouge is ground from the inside leaving an outside cutting edge. If a round cutter is desired, grind so that the cutting edge will be on the inside.

WING DIVIDERS

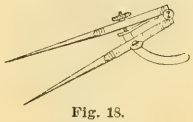


Fig. 18.

Fig. 18. Dividers are used for laying off circles and arcs and stepping off scrolls to find their length.

CALIPERS

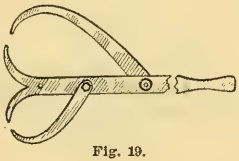


Fig. 19.

Fig. 19. Calipers are used to measure diameters, widths and thicknesses of forgings. Blacksmiths' calipers are generally made double so that one side may be set for the width and the other side for the thickness. These are made with a long handle so as to keep the hands from being burnt when measuring red hot forgings.

GAUGES

Fig. 20.

Fig. 20. Gauges are used where there are a number of pieces of the same size to be made. Some gauges are adjustable, others are made for one size only.

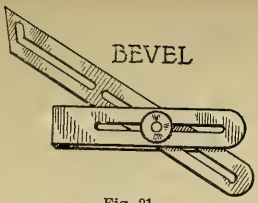


Fig. 21.

Fig. 21. The bevel square can be adjusted to any angle. It can therefore be used for laying out or trying angles.

Fig. 22.

Fig. 22. Trammel points are used when work is to be lengthened or shortened. The distance is laid off by a set of punch marks and tried by the trammel points for accuracy. They are also used to lay out large circles.

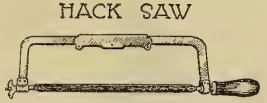


Fig. 23.

Fig. 23. Hack saws are used for sawing iron or soft steel. Care should be taken that the blade is in the saw properly and drawn tightly. The saw should be kept straight in the cut and gripped at each end, a slight pressure being applied on the forward stroke. The strokes should be at the rate of 60 per minute.

Fig. 24.

Fig. 24. Heading tools are used when heads or collars are to be made on forgings. The hole is slightly tapered and the forging should enter at the small end.

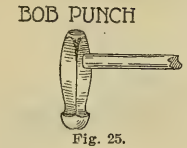


Fig. 25.

Fig. 25. A bob-punch is used for making counter sinks and chamfering the inside edge of a solid eye and to make a depression for jump welds. The point of the punch is oval.

Fig. 26.

Fig. 26. Mandrels are of various shapes and sizes. The small mandrels are made with shanks to fit in the hardy-hole of the anvil. Large mandrels are about 12″ in diameter at the largest end and 5′ long, conical in shape and generally made of cast iron. The best mandrels have a channel running lengthwise about 1¼″ wide and deep which is very convenient for the tongs or when rings or bands have links or eye bolts.

Mandrels are used for truing rings or bands. Round rings or bands should be evenly heated, then trued by striking over the part that does not touch the mandrel. Flat or square stock should be turned to prevent taking the taper of the mandrel.

SWAGE BLOCK AND STAND

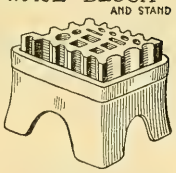


Fig. 27.

Fig. 27. A swage block is indispensable in a small shop as it combines nearly every shape and size of bottom swage. When lying on its side it will head quite a number of sizes and shapes. The swage block is generally fitted with a stand that will hold it upright or lying on its side.

FACE OR SURFACE PLATE

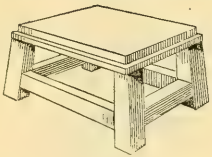
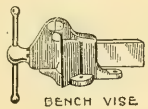


Fig. 28.

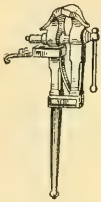
Fig. 28. Surface plates are made of cast iron about 3″ thick, 24″ wide and 3′ long. The face is absolutely true and is used for testing the straightness of forgings.

VISES



BENCH VISE
Fig. 29.

Fig. 29. Bench vises are used when filing and for light forge work.



BLACKSMITH'S VISE
Fig. 30.

Fig. 30. Blacksmith vises are forged from wrought iron or soft steel. They are made to stand hard usage.
The blacksmith vise is fastened to the bench and has a leg supporting it from the floor. It is used for heavy work.

DRIFT PIN

Fig. 31.

Fig. 31. To make eyes or holes accurately, drift pins of the required size and shape are driven through the metal. The stock should be resting on a suitable bottom tool.

Forge tools with shanks that fit into the hardy-hole of the anvil should go in without forcing; if they are forced in, they are liable to stick and cause delay and trouble.

The heads of tools that are hammered on should never be allowed to spread or batter. They should be dressed and kept in shape, otherwise if hit a glancing blow, pieces are likely to fly off and injure someone.

WROUGHT IRON.

Wrought iron is the purest form of commercial iron, the impurities being worked out by the puddling process.

In this process the pig iron is melted in a puddling furnace. When melted, the iron is stirred with large iron hooks by the puddler so as to expose every part of the bath to the flame. The temperature of the furnace is kept high enough to melt the pig iron but not high enough to keep the pure iron melted. When the impurities are separated from the iron, the iron congeals and is then formed into balls. These balls are taken to steam hammers or squeezers and hammered or rolled into blooms. The iron is then reheated and rolled into finished shapes. It is never cast but always forged to shape. It is malleable and will not harden noticeably when suddenly cooled in water and is very easily welded. Iron welds at 2733° fahrenheit and melts at 3000°. Cast iron melts at 2000°. Steel melts at 2400°.

SOFT OR MILD STEEL.

Soft or mild steel is generally made by the Bessemer or open hearth process.

The Bessemer process is named after its inventor, Sir Henry Bessemer. It was first used in England about 1856.

The pig iron or ore is heated in the blast furnace, then poured into ladles and carried to a mixer which is a large furnace mounted on trunnions. The metal is mixed so as to insure a uniform analysis and is then poured into ladles and carried to a converter. The converter is a pear shaped vessel mounted on trunnions. It has a double bottom, the upper one being full of holes. The converter is tilted to one side to receive the metal and as it is righted, compressed air is forced in between the inner and outer shells of the bottom to keep the metal out of the holes or tuyeres. As the air is forced in, it runs upwards through the molten metal, causing most of the carbon and impurities to burn or oxidize, leaving the steel with about ten points carbon. A point is one one-hundredth part of one per cent and is spoken of as temper by steel men. At first the impurities burn with a dazzling flame for about fifteen minutes, after which it gradually dies out. This gives the signal that the blow is over. The converter is again turned on its side and the air shut off.

If a higher carbon steel is required, the desired amount of spiegeleisen or ferromanganese is added while it is in a liquid state. It is now ready to be poured into ladles and then into ingot molds and allowed to cool slightly; the molds are then stripped from the ingots. The ingots are put into furnaces known as soaking pits until they can be taken to the rolls where they are rolled to shape.

Open Hearth Process

The open hearth steel process is sometimes called the Siemens-Martin process. It is similar to the puddling process, but is done on a larger scale. The open hearth furnace has a capacity of 40 to 200 tons and is heated with gas made from bituminous coal. The gas and air needed for its combustion are heated to about 1000° fahrenheit before entering the combustion chamber by passing through socalled regenerative chambers. There are two chambers filled with checker work of brick. While one side is being used, the other is being heated by the hot air and gases from the furnace. As the one used becomes cool, the air and gas are reversed so as to pass through the heated one. Owing to this arrangement a very high temperature can be maintained keeping the iron in a liquid state after its carbon has been removed. This molten metal is kept stirred by adding iron scales or other oxides which keep the metal agitated. The open hearth process has two advantages over the Bessemer process. First, it is always under control and tests can be taken at any time. Second, owing to its intense heat scrap iron and steel can be used as well as pig iron or ore. When the heat is ready the furnace is tapped and the metal is run into a large ladle which in turn is tapped from the bottom and the metal is poured into ingot molds. It is then finished as in the Bessemer process.

CALCULATION OF STOCK FOR FORGING.

In making a forging that has different sized parts such as a small section between larger sections, it is necessary to calculate the amount of stock required before the depressions for the shoulders are made. This is an easy matter if we will only bear in mind that changing the shape does not change the volume. The method generally used is cubic measure.

Problem: How much stock will be required to make a section 1″ square and 10″ long with a section on each end 2″ square and 4″ long.

First, find the number of cubic inches in the section 1″ square by 10″ long. The answer is 1″ x 1″ x 10″ equals 10 cubic inches. Second, find the number of cubic inches in a piece of 2″ square stock 1″ long. It will contain 2″ x 2″ x 1″ which equals 4 cubic inches. Then 10 divided by 4 equals 2½ or the length in inches required for the 10″ section. Now add to this the two 4″ ends making 10½″ in all. This will be the length required.

If the 10″ section is round, first square the diameter, then multiply by .7854. Multiplying by the length 10 and dividing by 4, equals 1.9635 or practically 2″, as there is always a little allowed for waste.

To find the length of stock necessary to draw a square point 2″ long on a bar 2″ square, we find the volume of the pyramid 2″ x 2″ x 2/2 or 4 cubic inches, then dividing by the cross sectional areas of the rod or 2″ by 2″, we get 1″ for the length.

If the point is to be rounded to a length of 2″ from 2″ round stock, we must find the volume of the cone 2″ long with a base of 2″ diameter. The volume would be 2 x .7854 x 2/2 which gives 1.5708 cubic inches. Dividing this by the cross sectional area of the rod, or 2 x .7854, which equals 1.5708 we get 1 or the length in inches of the round bar to forge the point.

In a similar manner we calculate forging a square point from round stock or a round point from square stock.

To calculate the length of stock for rings or bands, remember, if the heat is uniform, the center will not change. Therefore, measure the stock through the center to find the length. In rings or bands use the distance through the center and from center to center of stock. This should be multiplied by 3.1416 or 22/7. When welding allow for waste.

To measure the length of stock for irregular shapes or scrolls, step off distances along the center of the stock with dividers, remembering the number of steps. Sometimes a soft wire or string is used, following the center line; then the wire or string is straightened out, giving the length required.

To calculate the weight of stock, first find the cubic inches then multiply by the following which will give the approximate weight: For cast iron .26 lbs., wrought iron .277 lbs., soft steel .283 lbs.

DRAWING-

Fig. 32.

Fig. 32. When heated iron or steel is hammered or pressed, it can be lengthened or widened as desired.

This is expressed in blacksmithing as "drawing."

To keep square or flat stock from becoming diamond shaped always turn it the full quarter or half way over and strike a perfectly square blow.

STEPS IN REDUCING STOCK TO ROUND

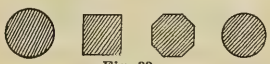


Fig. 33.

Fig. 33. In drawing metal that is to be round, draw it square to size; then break down the corners, making it octagonal. Then round it up with as few blows as possible, using top and bottom swages to finish.

OVER HANGING BLOW IN POINTING

Fig. 34.

Fig. 34. In drawing a point the stock should be held so that the sides of the point are level on the anvil and the point extending to the outer edge of the anvil. The point should never be hammered below a red heat. When reheating be very careful as the point is smaller and will heat faster and is likely to burn off.

In drawing square points, first draw to a short sharp point then work back to the proper length.

A round point should first be drawn to a short square point, then proceed as in drawing round stock.

A chisel point is a wide flat point.

UPSETTING

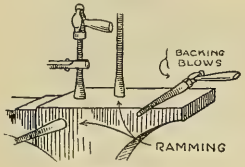


Fig. 35.

Fig. 35. Upsetting is the opposite of drawing. The length of the stock becomes shortened, and the width, thickness or diameter increases. Long pieces are generally heated where they are to be upset and rammed against the side or on the face of the anvil or on upsetting blocks which are set in the floor on a secure foundation. Short pieces are held upright on the anvil, the hammering being done directly on the upper end. In upsetting, care should be taken to keep the stock straight.

Fig. 36.

Fig. 36. Grip the stock in two places and twist in opposite directions. On light stock twisting may be accomplished either hot or cold; the hot will give a closer twist. Heavy work should always be heated. Round stock with flat or square parts may be lined up by twisting, without any noticeable effect on the shape of the stock.

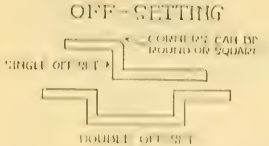


Fig. 37.

Fig. 37. Off setting is the method of changing the level of a surface or a forging by a double bend. They may be in line with one another or at different angles or they may form a double offset to avoid other parts of machines where a straight piece would be impossible.

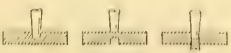


Fig. 38.

Fig. 38. With either hand or handle punch drive one-half to two-thirds through from one side, cooling the punch in cold water when necessary. The stock is then turned over and punched all the way through from this side. If you punch through from one side it will not leave a clean hole; there will be a burr on the side it came through. If the punch is allowed to become hot it will upset in the hole and bind, causing delay and unnecessary work. If the stock is very thick, a piece of coal may be put in the hole to keep the end of the punch cool and form a gas that will help remove it.

Shrinking

To shrink bands around broken parts of machinery or collars on shafts so that they will fit securely, the band or collar is made slightly smaller. They are then brought to a red heat, causing them to expand, and put in place. When cooled they will contract and fit tightly.

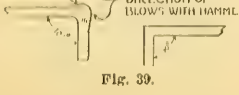


Fig. 39.

Fig. 39. Always bend over a round edge. A sharp edge is liable to cut and cause galling thus weakening the forging.

Do not heat any longer than necessary. If the heat is too short the outside will draw more than the inside will upset, making the stock at the bend much smaller than if the heat were the right length.

To make a bend that is square inside and out, two methods are used. One is to take stock that is large enough and draw it out on each end, leaving enough stock at the bend to square the outside corners. The other is to take stock the required size and upset at the bend until there is enough stock to square the outside corners.

Heat and bend to 100° with a fillet on the inside. One end is placed on the anvil the other is held either in the hand or with tongs. The stock should be hammered on either side in such a manner as to draw gradually to the corner. Square up in this manner with the necessary straightening.

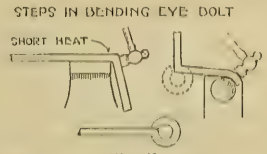


Fig. 40.

Fig. 40. To make an eye, calculate the required length of stock, using the same method as for rings or bands and mark with a center punch. Heat and bend to an angle of 100°. Then start at the end to bend over the horn of the anvil, in the opposite direction at the correct radius until the eye is complete. If the eye is to be welded allow for scarfing.

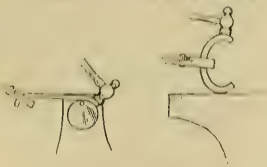


Fig. 41.

Fig. 41. In making rings or bands, first calculate the length of stock necessary. If it is to be welded allow enough to take care of waste in upsetting and welding. Bend 2″ to 4″ of each end to the correct radius. If the ring or band is small, heat the entire length to an even heat and bend by placing the stock upright, with one end on the anvil striking the other end with a hand or sledge hammer, alternating until the ends meet. Then true up on the horn of the anvil or on the mandrel.

For large rings or bands heat 6″ to 12″ beyond the bent end, clamp the bent part to a former of the correct radius. Then bend the heated portion, continue to heat, clamp and bend until the ring or band is completed. If the rings or bands are to be welded, the scarfs should be on opposite sides and overlap slightly.

Small round, square and thin stock is sometimes bent cold. This is done around a former that is slightly smaller than the required inside diameter, as the stock will spring out some when the clamps are released.

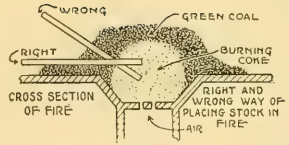


Fig. 42.

Fig. 42. Welding is the method of joining two or more pieces together by hammering or pressing at a welding heat. The important points are upsetting, scarfing, condition of the fire, proper heating and hammering.

Upsetting

Upsetting takes care of the loss of material due to heating and hammering as the piece should be the original size when finished.

Fig. 43.

Fig. 43. One method for scarfing is to taper one side to one and one-half times the thickness of the stock by backing-up blows with a hammer at the proper angle. If there is a helper, the work is done with a fuller starting on the upper side as far back as necessary, moving the fuller forward at each blow, and striking the edge of the scarf so that it will not be any wider than the stock but a little narrower at the end. If stock is round, the scarfs should be drawn almost to a point. Scarfs should always be made higher in the center so that, when the weld is started, the impurities will be forced out. If the edges catch first, the impurities are likely to be retained, thus making an inferior weld. These scarfs are used in lap-welding.

There should be 3" or more of live fire, free from dirt and clinkers and enough coke on top to hold the heat. Then banks of green coal are placed on each side of the fire.

The parts to be welded are placed scarfs down into the fire. Heating should be slow at first to give the large part of the scarf time to heat through without burning off the edge. Then put on more blast as it approaches a welding heat.

The welding heat in iron and soft steel is between the socalled white heat and the burning heat. If burned, the metal in the weld will be destroyed.

Great care should be taken with tool and high carbon steel. If brought to a white heat, the metal will burn, and when struck with a hammer, it will fall to pieces. The welding heat for tool or high carbon steel is lower than for iron or mild steel therefore a flux should always be used. In some cases a welding compound is advised so as to save bringing the steel to a high temperature.

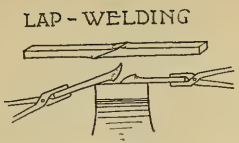


Fig. 44.

Fig. 44. When the welding heat is reached, the parts are brought out of the fire and struck on the anvil so as to remove any impurities that might cling to the scarf.

One piece is placed on the anvil, the other is rested on the edge of the anvil and guided into place. The end of the scarf should extend slightly beyond the heel of the first one but not beyond the upset part. As the student becomes more experienced, he may have the first piece extend slightly over the edge of the anvil to prevent the scarf from being cooled too rapidly.

As the welding heat only lasts a few seconds the student should practice the different movements before trying to weld. The metal should be hammered hard enough so that the blows will penetrate through the stock, as this packs and refinds the metal. Remove the hammer marks with a flatter; if round stock use swages.

Strike a few light rapid blows with the hammer to make it stick; hammering should then begin in earnest, catching the scarfs on the upper side as quickly as possible. Then turn over and catch the scarfs on the lower side, and finish with the necessary hammering on the edges. If the weld cools before it is finished, reheat to a welding heat then hammer where necessary.

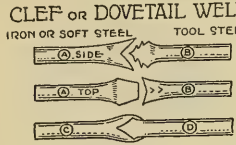


Fig. 45.

Fig. 45. The clef or dovetail weld is used when large parts are welded together and when high carbon or tool steel is welded to soft steel or iron. The tool steel or the part that requires the greatest care in welding should be the insert, as the milder material will then be on the outside to protect it.

The stock is first upset, the outside piece is split as in Fig. A, and the sides scarfed, keeping the same width as the stock. The other piece is forged wedge shape as in Fig. B. to fit into it, the end being slightly wider than the other scarf. A couple of burrs are thrown up on each side of the insert with the corner of a sharp chisel or a diamond point. The insert is cooled while the outside is heated. They are then put together on the anvil, and the insert driven in tightly, while the outside is closed down as at C. The outside piece being hot the burrs cut into it and fasten the pieces securely. If tool steel, or high carbon steel, is to be welded, a welding compound should be sprinkled into the outside piece before it is closed down on the insert. Heat very slowly and turn repeatedly. The outside piece being hot it is likely to become overheated before the insert reaches a welding heat. It is then brought out on the anvil and hammered up as in lap-welding.

Fig. 46.

Fig. 46. When pieces are too thin to be joined by the clef or lap-weld, they are scarfed, split and bent as in Fig. A, then placed together as at B. Heat and weld in the usual way.

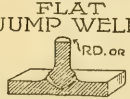


Fig. 47.

Fig. 47. When a stem or shank is to be welded on wide flat stock, the stem or shank is upset with a short heat and a scarf is worked out all around. The scarf should be shaped so that the end will come in contact first and as the weld is hammered together, the impurities will be forced out. The flat stock is upset and a place to receive the stem is worked out with a bob-punch. The two pieces are brought to a welding heat, the stem is driven in and the scarf caught with the peen of the hammer or fuller.

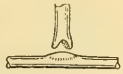


Fig. 48.

Fig. 48. When both pieces are round, the stem is split as in the clef weld. The piece to which it is welded is upset and scarfed to one side to receive it.

Lap-welding as used in the welding of links.

FACE OF HAMMER SCARFING
WITH OVER HANGING BLOWS
CLOSED IN HERE
MOVE UP AND DOWN WHILE HAMMERING
PREPARING AND WELDING LINKS

Fig. 49.

Fig. 49. Find the length of stock required, and bend over the horn of the anvil to shape as at A. While in this position, gradually move off the anvil striking overhanging blows to scarf, turn over and scarf other end as at B, close end in a little and lap over as at C. Put into the fire and turn repeatedly. It is then brought out on the anvil and the scarfs are welded as in lap-welding. To catch the outside and inside, it is put on the horn of the anvil as at D, and finished.

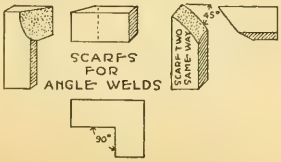


Fig. 50.

Fig. 50. Upset and scarf as shown in the illustrations. Heat and weld as in lap-welding, keeping the outside corners square and of the same thickness as the metal with a slight fillet on the inside. Try with the square and finish with the flatter.

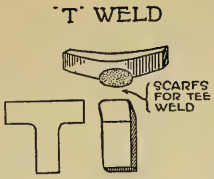


Fig. 51.

Fig. 51. Upset and scarf as shown in the illustrations. Heat and weld then finish up as in the angle weld.

ANNEALING.

Annealing is the opposite of hardening. That is, in annealing we cool off as slowly as possible from the hardening heat, the slower the softer, whereas in hardening we cool off as quickly as possible, the quicker the harder.

There are several methods of annealing. The one used in small shops is to heat to a uniform red heat and then to cool slowly in boxes filled with charcoal or air slacked lime. The boxes must be large enough to allow a thick layer of charcoal or lime on all sides of the forging. Another method is to place the hot stock between two pieces of wood, covering entirely with dry ashes and leaving until cold.

In shops where a large amount of annealing is done the box annealing method is used. Boxes are made of either cast iron or sheet steel about 12′ square and 3′ long. The bottom is covered about 1½″ deep with powdered charcoal. The forgings are placed on this about 1½″ apart and 1½″ from the sides. One and one-half inches of charcoal is placed on this, then another layer of forgings and so on until the box is filled, allowing 1½″ on top for the charcoal. The cover is put on and "luted" or daubed up with clay, to keep the direct heat out. The boxes are heated to a uniform red heat for several hours and then allowed to cool off in the furnace.

Water annealing. The forging is heated, cooled in the air until the red heat has disappeared (testing in a dark place) and then cooled in water. This method is used only in an emergency as the results are not always satisfactory.

CASE HARDENING.

Machine parts that require great strength and a hard wearing surface are made of soft steel or iron with the wearing surface case-hardened.

Case-hardening is the process of adding carbon to the outer "skin," in other words making the surface similar to tool steel.

Two methods are used. First, when there are only a few pieces, or in an emergency, heat the parts to a good red heat and cover with a carbonaceous substance such as potash or cyanide of potassium. While still at a red heat, cool quickly. When cooled the surface should be glass hard. (Caution). These chemicals are deadly poisons and care should be taken when handling them.

Second: This way is known as pack hardening. The parts are packed in the same manner as for annealing. The packing material used must contain carbon such as charred raw bone and charcoal, powdered and mixed, using equal quantities. The cover of the box should have several small holes drilled through it for the test wires. These test wires are inserted after the cover is in position and are forced through to the bottom. After a certain time has elapsed one of the wires is drawn out; if it is not red its full length, wait a while before drawing another. As soon as one is found to be red hot its entire length, the heat is timed from then on, generally four to five hours, or longer, if necessary, according to the depth of hardness required. The metal is then taken out of the furnace, separated from the packing material and cooled as quickly as possible. One or two test pieces are included in each heat. When these are cooled off, they are broken to determine the depth of the hardening. The appearance of the hardened part is noticeably different from that not hardened.

TOOL STEEL.

Tool steel is made by the crucible process. The crucible is made of clay and has a capacity of 50 to 80 lbs. It is charged with wrought iron, Swedish iron for the better grades, surrounded with charcoal and a little manganese. The cover is placed in position and the crucible is put in a hot furnace. After three hours, during which time the contents are melted, it is examined to determine the killing period, that is, the length of time required for the metal to become quiet and take a sufficient amount of silicon from the walls of the crucible. Silicon prevents blow holes. At the right time the crucible is taken out and the slag skimmed off. The metal is then poured into split molds. When cool the pipe end is cut off and the flaws are ground out. The billets are then brought to a forging heat, and hammered to size. Hammering refines and packs the grain of the metal.

High speed and alloy steels are generally made by this process, adding the necessary alloys.

FORGING OF TOOL STEEL.

There are different kinds of high carbon steel, therefore it is essential that the right steel be used for the work that is to be done.

Tool steel for forging should be heated in a furnace or a well charred fire, slowly and evenly, to about 1500° fahrenheit, never over, and when the steel cools to 1000° it should be reheated.

When forging thin flat steel, the blows on the edges should be light to keep the center from bending or straining, and the last blows should be delivered on the sides.

When reducing tool steel to round, use the same method as for iron or steel.

Forgings should always be annealed before machining or hardening. This will soften and relieve strains set up in forging.

HARDENING.

Hardening is the result of heating steel to the required temperature and cooling as quickly as possible.

To harden tool steel use the lowest heat at which it will harden properly. This is found by experimenting and is usually from about 1300° to 1500° fahrenheit.

To harden, quence steel at a rising temperature.

There are different kinds of hardening baths: water, the softer the better; brine, a mixture of salt and water; and oil such as linseed, fish, lard oils or oil compounds. Water, 60° to 70° fahrenheit, is generally used. Brine makes the steel harder than water; oil makes it softer but tougher and is used when elasticity and toughness are required as in springs or surgical instruments.

Tools that are to be hardened throughout are heated uniformly, then left in the bath until cold, to prevent the temper from running out. Tools that have holes or parts that will hold steam should be cooled with these parts up so that the steam can escape. If turned down in the bath they would hold the steam and the parts would remain soft.

Long thin pieces should be dipped in the hardening bath perpendicularly.

TEMPERATURE SCALE.

Name—	Centrigrade	Fahr.
White	1205	2210
Light yellow	1076	1975
Lemon	995	1823
Light salmon	941	1725
Salmon	899	1650
Bright red	842	1550
Cherry	745	1375
Medium cherry red	676	1250
Dark cherry red	634	1175
Blood red	566	1050
Black red	500	950

Temper colors or tarnish tints.

430° fahrenheit, faint yellow or light straw for tools for turning chilled iron rolls at slow speed.

450° fahrenheit, full yellow or dark straw for lathe and planer finishing tools, twist drills, threading dies, large taps and reamers.

475° fahrenheit, gold or full straw for thread cutting tools, stray bolt taps, small cutting tools, hammers, etc.

500° fahrenheit, brown or deep straw for quarry tools, punches and dies, mill picks and similar tools.

525° fahrenheit, purple for punches and dies, hot and cold chisels, blacksmiths' tools, general boilermakers' tools, shear knives, chipping chisels and a great variety of other tools.

550° fahrenheit, dark blue for smith tools and other tools which must stand considerable battering, yet which must hold good edges.

580° to 625° fahrenheit, light blue for springs, surgical instruments, etc.

TEMPERING.

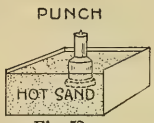


Fig. 52.

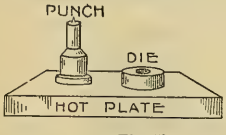


Fig. 53.

Tempering is reducing the extreme brittleness and relieving the strain after the tool has been hardened.

To temper tools that have been hardened throughout, first polish the tool then put it in hot sand (Fig. 52), or on iron (Fig. 53), that has been heated; this will reheat the stock and cause the temper to run. When the right color is reached, cool it off.

Another method is to heat a bath to the required temperature to produce the right temper. In commercial shops a pyrometer is used to be accurate. The tool is put in the bath and left until it reaches the heat of the bath and then taken out and cooled.

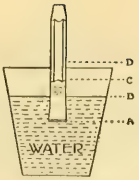


Fig. 51.

Some tools are hardened and tempered in the same heat. For example, the cold chisel is heated from A to D about 2½", then cooled in water from A to B by moving it up and down between B and C slightly, to prevent a water crack. (Fig. 54). When taken out of the hardening bath it is allowed to dry; then it is polished rapidly, otherwise the temper is liable to run out before the colors can be seen. When the right color has reached the cutting edge, in this case a dark blue, it is cooled off.

SPRING OR OIL TEMPERING.

Springs and tools that are bent in use, and when the pressure is relieved will resume their original shape, require elasticity rather than extreme hardness.

Springs are heated to the hardening temperature and cooled in oil, then taken out and the oil is burned or flashed off. The spring is then allowed to cool off in the air. Tools are left in the oil until cold, then the oil is drained off, the tool is cleaned and polished and the temper drawn.

High Speed Steel

High speed steels have had special alloys of iron such as chromium and tungsten added to them.

To forge, heat slowly and carefully to a lemon heat 1800° to 2000° and forge uniformly. Do not work the steel when it falls below 1700°; heat as often as necessary.

Hardening, the heat should be raised slowly to a cherry red 1400° and then raised quickly to a full white heat 2200° to 2250° or until the cutting edge starts to blister, then cool in air blast or oil.

To remove strain heat to about 600° and cool again in water. Grind with a dry abrasive wheel.

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